# Test Beams: Descriptions and Plans *

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**Abstract**

Worldwide test beam facilities, which will be useful in testing linear collider R&D prototype detectors, are briefly reviewed and future schedules for these test-beams are noted.

## 1 Introduction

With the development of detectors for the various linear colliders (LC) that are being considered, the need arises for test beams to evaluate prototype detectors. Test-beams exist at nearly all the major high energy laboratories around the world. Since a 0.5 - 1.0 TeV LC will be a worldwide effort it is appropriate to survey the needs for test-beams and to identify and characterize the existing test-beams.

The physics we want to study at the LC centers around the search for Higgs states and SUSY particles. Both physics and detector studies for the

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LC are described in reports from Asia [1, 2], Europe [3, 4, 5] and North America [6, 7], where physicists are co-operating within a world-wide study [8] to document physics and detector studies. Because of the small cross-sections for the e+e- production of these posited particles, the luminosity has to be high and the detectors have to satisfy demands that in some cases surpass those required for the LHC [9]. This is especially true for the LC tracking detectors and calorimeters where unprecedented accuracy is demanded for a variety of reasons: detector hermiticity, excellent charged particle momentum resolution, unsurpassed flavor tagging efficiency for $b$ and $c$ decays, and separation of $W's$ and $Z's$ that decay to hadronic final states. Present calorimeter designs call for the use of energy-flow algorithms in which the charged hadrons are measured with tracking, and the neutral hadrons are determined by subtracting the measured charged hadrons from the highly segmented and fine-grained hadronic calorimetry. Photons, electrons and positrons are measured with the EM calorimetry and the charged leptons $e$ and $\mu$ are measured using the tracking detectors.

At the present time there are candidate technologies for the detector systems in various stages of R&D. Examples include vertex detectors that plan to use new CCD's with thinner Si and parallel readout [10, 11, 12] or other new devices such as monolithic active pixel sensors MAPS [13, 14], hybrid active pixel detectors HAPS [15, 16] or DEPFET (depleted FET) detectors [17, 18]. Radially beyond the vertex detectors, tracking candidate technologies include jet drift chambers, time-projection chambers and/or Si layers at large radius. EM calorimeters being considered are [19]: (1) W sheets sandwiched with Si pad readout, or (2) scintillator tiles with fiber readout that vary in size from $3x3cm^2$ to $5x5cm^2$. Scintillator strips are also being considered for EM calorimetry and for EM shower max detectors, and a crystal EM calorimeter is also being developed. Hadronic calorimetry R&D is focussed on either Fe or Pb plates as the absorber and tile/fiber readout. In addition to conventional pad readout via fibers, studies are in progress to use other techniques such as GEMs, RPCs or wire chambers. There is also interest in using very small scintillator pads, $\sim 1cm^2$, with a simple digital readout, to form a digital calorimeter in which cells with energy deposition above a threshold would count as 1 and those below the threshold would count as 0. Because the proposed calorimeters are relatively thin there is a need to understand how the muon system can contribute to improving resolution in the energy-flow algorithms, especially in those cases where neutrons and long-lived neutral K mesons don't interact in the upstream calorimetry.

This brief R&D list is incomplete and necessarily selective. More details about the R&D program can be found in these conference proceedings and an article on LC R&D that is the result of a survey conducted by an international LC R&D committee [20].

# 2 High Energy Test Beams

The international laboratories around the world recognize the need for LC detector R&D. In fact most of them are engaged in detector R&D and others plan to make facilities available for testing LC detector prototypes. We review here the facilities that are appropriate for some aspects of LC detector R&D.

## 2.1 KEK

KEK near Tsukuba, Japan has two test beams in its East Counter Hall that are derived from the 12 $GeV$ proton synchrotron [21]. The two test beams are designated $\pi 2$ and $T1$. $\pi 2$ has a maximum energy of 4 $GeV$ while $T1$'s maximum energy reaches 2 $GeV$. The momentum bite of these unseparated beams is $(\Delta p)/p \approx 1\%$ (FWHM). Cerenkov counters exist in both beamlines to separate $e's$ from $\pi's$. $\pi 2$ has an additional momentum analyzing magnet, while $T1$ does not.

A special feature of these beams is their ability to operate at low momenta. $\pi 2$ runs stably at 0.5 $GeV$ and $T1$ can operate down to a few hundred $MeV$. Operation of the high energy beams at other laboratories that reach beyond $\sim 100$ $GeV$, discussed later in this report, is typically difficult below $\sim 5$ $GeV$.

KEK test beam operation is expected in the fall or winter of 2003 and until the summer of 2004 when the test beam facilities will close for construction of the JHF.

## 2.2 DESY

DESY has three test beams designated Teststrahl 21, 22 and 24. These $e+$ $e-$ beams are generated from bremsstrahlung derived from a carbon fiber in DESY II. The bremsstrahlung is subsequently converted to $e+e-$ pairs as it passes through a $1-10$ $mm$ thick piece of Cu or Al. The electrons, positrons and unconverted photons are passed through a sweeping magnet and on to a collimator for momentum and sign selection. In this way it is possible to generate $e+$ or $e-$ beams in the momentum range $1-6$ $GeV/c$. Typically the maximum intensity is $\sim 1$ $kHz/cm^2(avg)$.

The DESY test beams are particulary useful for testing EM calorimeter prototypes, shower-max detectors and photon detectors. Descriptions of the DESY test beams [22] are available on the Web at:
http://desyntwww.desy.de/~testbeam/welcome.html.

## 2.3 CERN

CERN has test beams in both the West and North areas that are summarized in Tables 1 and 2 [23]. The web-site that contains descriptions of the CERN Beamlines is: http://sl.web.cern.ch/SL/eagroup/beams.html.

Table 1 - CERN West Area Beams

| Beam | $P_{max}(GeV/c)$ | Intensity for $10^{12}$ p | Beam Type |
|---|---|---|---|
| H3 | 250 | $\sim 2X10^7$ secondaries | Parent for X5,X7 |
| X5 | 250 | $10^2-10^4/10^7$ inc. part. | Test beam:$e,\pi,\mu$ |
| X7 | 250 | $10^2-10^4/10^7$ inc. part. | Test beam:$e,\pi,\mu$ |

The secondary beam intensities listed in Tables 1 and 2 are for 400 $GeV/c$ protons incident on the production target. Downstream of the X5 beam dump in the West Area there is a Gamma Irradiation Facility (GIF) that is derived from a $Cs^{137}$ source. The main purpose of this facility has been to provide a background for testing LHC prototype detectors with muons that penetrate the X5 beam dump in the presence the GIF produced background.

Beamlines H2, H4, H6 and H8 can provide high purity electron beams for EM calorimeter calibration at momenta below 250 $GeV/c$. These same beams can also be used to provide hadrons and muons at momenta below 350 $GeV/c$.

| Table 2 - CERN North Area Beams | | | |
|---|---|---|---|
| Beam | $P_{max}(GeV/c)$ | Intensity for $10^{12}$ p | Beam Type |
| H2 | 400 | $9x10^7\pi^+$ at 200 $GeV/c$ | High-energy $had/e$; |
| | | $3x10^7\pi^-$ at 200 $GeV/c$ | also test beams. |
| | | $4x10^6e^{\pm}$ at 150 $GeV/c$ | |
| | | $1x10^5Pb$ at 400 $GeV/Z$ | Heavy ion beam. |
| H4 | 400 | $\pi, e$ fluxes $\sim$ H2 | High-energy $had/e$; |
| | | $\sim 10^7$ p at 400 $GeV/c$ | Atten. *pri*. beam. |
| | | $\sim 10^7$ Pb at 400 $GeV/Z$ | Heavy ion beam. |
| H6 | 205 | $10^8$ $\pi^+$ at 150 $GeV/c$ | Med. E *had* beam |
| | | $4x10^7$ $\pi^-$ at 150 $GeV/c$ | To make *tert*. beams |
| H8 | 400 | $\sim 10^7$ p's at 400 $GeV/c$ | Atten. pri. beam. |
| | | $2x10^8$ $\pi^+$ at 200 $GeV/c$ | High-energy $had/e$; |
| | | $7x10^7$ $\pi^-$ at 200 $GeV/c$ | |
| | | $\sim 10^6$ Pb at 400 $GeV/Z$ | Heavy ion beam. |

The X5 and X7 beamlines will be operational in 2003 and 2004. No PS/SPS operation is planned for 2005 and thus no West or North Area beam is expected in 2005. After the Jeju meeting it was decided that the West Area beams will be stopped at the end of 2004. However, the North Area beams will continue to be operated in 2006 perhaps with some financial constraints.

There are several test beams in the East Area at the PS [24].

## 2.4 Fermilab

The fixed target beams at Fermilab are in a state of transition. The future program at the Lab will feature experiments that use the 120 $GeV$ beam from the Main Injector (MI). There is also a test beam that is generated from the 120 $GeV$ MI beam. This beam is currently installed and it is being commissioned as running-time and resources permit. The Fermilab test beam passes down the M6 beamline and terminates in the Meson Lab. It is called MTest [25, 26]. The web-site that contains information on MTest is:
http://www-ppd.fnal.gov/mtbf-w.

The experimental area for MTest is expected to serve six user stations that are in series: MT6A1-2 and MT6B1-4. These two general locations are equipped with beamline instrumentation, data and HV cables, trigger and DAQ instrumentation, gases, air conditioning, etc.

The MTest beam consists of secondaries from a target that is bombarded by 120 $GeV$ MI protons incident on an upstream Al target at $0^o$. There are two modes of operation:
• Proton - $\sim 1$ $MHz$ of 120 $GeV$ protons;
• Pion - $\sim 50$ $kHz$ of 5 - 80 $GeV$ secondaries (the rate depends on E).
In the Pion mode the beam is: $e's \sim 10-20\%$, $\mu's \sim 5\%$ and $\pi's \sim 80\%$. The beam size at the MTest experimental area is $\sim 1cm^2$. There are two Cerenkov counters for tagging electrons in the beamline and 0.5 & 1.0 mm beam PWC's. Negative polarity is possible.

There is also a Booster Accelerator Radiation Damage Facility at Fermilab that has been used to measure radiation damage in Si detectors. As an example, this beam was used to deliver 2.1 MRads of radiation to study damage in D0's prototype Si micro-strip detectors.

## 2.5 SLAC

For the past several years the SLAC Final Focus Test Beam (FFTB) has been used for testing detectors in addition to its primary role as a facility

to measure final-focus beam parameters. There are four possible modes of operation. All provide beam pulses 6$ps$ long at 1 - 30 $Hz$ depending on the accelerator program:
• Low intensity ($< 10^3 e's$ per pulse): $e^+$ or $e^-$ with 5 $GeV \leq p_e \leq 20$ $GeV$ and $\leq 10^3$ $e's$ per pulse. Operation with single (binomial count distribution) $e's$ per pulse is also possible. Operation at energies 20 $GeV \leq p_e \leq 45$ $GeV$ is possible but it is very expensive and parasitic to PEP/BaBar operation.
• High intensity: $e^+$ or $e^-$ are available for very thin materials with $p_e = 28.5$ $GeV$.
• Bremsstrahlung: $p_\gamma^{max} \leq 28.5$ $GeV$ for $x \leq 0.02 * X_o$ and $\leq 10^{10} e$ per pulse. The photon rate can be adjusted to $\sim 1\gamma$ per pulse and the experimenter can provide a tagging system.
• Hadrons: Hadrons have been produced at wider angles from a $Be$ target. The proton yield has been maximized at 13 $GeV$ where they are 0.44% of the beam (mostly positrons and pions).

There are space constraints in the FFTB area with about one meter available transverse to the beam and $\sim$ 2m along the beamline.

Operation of the FFTB is planned to be terminated in or after 2005 for installation of the LCLS, and the beamline is presently in heavy use for advanced accelerator R&D. Tests can be scheduled, but people wishing to use the facility should plan well in advance to be worked into the schedule.

Tests have also been carried out in recent years at End Station A, where however, the competing experimental program has been very full. Unfortunately, due to a lack of funds, the experimental program at End Station A will terminate in about one year [27].

# 3 Conclusion

It is clear the requirements for a linear collider detector demand rigorous designs and significant testing of prototype detectors. Paper studies, calculations, bench tests, etc. are important prerequisites for building a successful experiment, but beam tests will let us choose the most appropriate technologies on which we should base our future.

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